

DOUBLE SLIT-VALVE DOORS FOR PLASMA PROCESSING

Inventors:
Michael D. Welch
Hongqing Shan
Paul E. Luscher
Evans Y. Lee
James D. Carducci
Siamak Salimian

CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation of application no. 09/711,191 filed 11/13/2000, which is a divisional of application no. 09/111,251 filed 7/03/1998, now US patent 6,192,827.

FIELD OF THE INVENTION

This invention relates to the construction of vacuum processing chambers used in processing of substrates for deposition and removal of materials. A particular chamber configuration using a specialized liner is disclosed.

BACKGROUND OF THE INVENTION

In general, vacuum processing chambers for processing substrates include a substrate transfer opening, commonly known as a slit valve. A slit passage associated with the slit valve is commonly used to transfer substrates into and out of the processing chamber between processing cycles. Commonly a robot extends from a cluster tool through a slit valve opening through the slit valve passage to deliver or remove a substrate to be processed to or from a processing location in the vacuum processing chamber. Once the substrate transfer at the substrate processing location is complete, the robot is retracted through the slit valve opening and back into the cluster tool. The slit valve opening is commonly sealed at an outside surface of the chamber body by a blocking plate which moves over the slit valve opening, in a coordinated motion with the movement of the robot and substrate into and out of the processing chamber. Plasma is often used in a processing chamber to enhance the process being performed. In a typical arrangement of a vacuum processing chamber, where a plasma is utilized to initiate or enhance process activity, the processing chamber and all internal services exposed to the plasma and the chemical by products are affected and can become coated with chemical byproducts of the process being performed.

Typically, the walls of the processing chamber are at least several inches thick to provide a sturdy chamber wall for processing activity. Thus, the opening in the side of the processing chamber which allows substrates to be transferred into and out of the chamber, the slit valve passage, presents a large tunnel-like opening which creates a geometric discontinuity at the inside surface of the processing chamber. The presence of a large cavity hole (the opening of the substrate transfer passage) adjacent to the space of the central processing location allows the plasma envelope which is present during plasma processing at the substrate processing location to expand into the cavity of the slit valve passage. The expansion of the plasma envelope into the cavity of the slit valve passage creates a distortion in the portion of the plasma situated adjacent to the cavity such that the plasma flux over the substrate in the area near the slit valve passage is affected, such that the deposition or etch taking place in that area is not uniform with other areas of the substrate where such distortion is not present.

Further, the internal surfaces of the slit valve passage, including the inside (process chamber facing side) of the slit valve door, are also subject to deposition and accumulation from the chemical process taking place in the chamber. Deposition on the inside surfaces of the slit valve passage and the slit valve door, require that any cleaning of the chamber (whether wet or dry) extend to include such surfaces. A thorough cleaning of the slit valve door requires that it also be removed so that the full area of the door all the way to the sealing limit be cleaned. In most instances, door cleaning requires that the cluster tool be removed from service so that cleaning of one chamber does not cause potential contaminants from one chamber serviced by the cluster tool to be carried over into a second chamber serviced by the same cluster tool.

The heavy duty sturdy construction of the processing chamber body and its liners finds no ready solution to the problem of the open cavity resulting from the slit valve passageway. Until now there has been no solution to overcome these anomalies of prior art devices, in that all prior doors are constructed in a configuration that gives rise to particles in the processing chamber.

SUMMARY OF THE INVENTION

A configuration according to the present invention overcomes the drawbacks of the prior art by providing an internal slit passage door which is cleverly constructed to improve the plasma uniformity over the substrate processing location and prevent deposition of chemical byproducts (such as polymers) in the slit valve passage. This second "internal" slit passage door is constructed as part of the chamber liner assembly so that when the chamber liner is replaced or a wet clean of the chamber liner is performed, the door is replaced and cleaned at the same time.

One configuration according to the invention includes a chamber body enclosing a substrate processing location space. The chamber body includes a slit passage extending from an outside surface of the body to the substrate processing location space, the slit passage being sized to pass a substrate therethrough. An outer slit valve door is positioned near the outside of the substrate transfer passage to seal the outer end of the slit passage to the chamber. An inner slit passage door is positioned in an inner portion of the substrate transfer passage to block the substrate transfer slit passage at a location near of adjacent to the substrate processing location.

Another configuration according to the invention can be defined with respect to a liner surrounding a substrate processing location in the vacuum processing chamber where the liner includes a substrate transfer opening therethrough. A liner door is selectively movable from an open position where the substrate to be processed can be passed, to a closed position where the liner door is located in close proximity to, but not touching the surrounding liner around the substrate transfer opening such that the edges of the door overlap edges of the substrate transfer opening. The overlap should preferably be approximately a half inch. The gap between the door in its fully closed position and the surrounding liner is in the range of several tens of thousands of an inch (several times 0.254mm) all around, but the door never touches the liner during operation. The door is curved to match the configuration of a curved liner, for example, a circular liner configuration. The movement of the door is vertical and selectively supported and controlled through a series of bellows which act as the vacuum limit of the processing chamber. The vertical motion limit of the door is precisely set by a set of soft stops which prevent the door from touching the liner.

To reduce the chances for particle contamination, the bottom and top portions of the door are beveled to matched opposed beveled portions of the inner liner. With such a configuration the buildup of deposited material on the inner surface of the door will not interfere with raising the door, as the clearance between the door and liner will increase with each incremental distance that the door is moved from its fully closed position towards an open position.

The invention further includes a method for reducing the buildup of process byproducts on the surfaces of a substrate transfer passage and for improving the uniformity of plasma in a vacuum processing chamber utilizing the steps of: providing a movable door to selectively block the substrate transfer passage at a location adjacent to the substrate processing location in the vacuum processing chamber, and moving the movable door out of the substrate transfer passage when a substrate is being transferred to or from the substrate processing location. The door and door support structure may be movable between a door open position and a door closed position without rubbing contact between any

two items within the vacuum limits of the processing chamber.

The door is opened simultaneously with the external slit valve door to permit passage of a substrate into and out of the chamber (for example, by a robot blade). The support for the door prevents lateral movement of the door and assists in positioning it precisely in its down position against a hard stop.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a processing chamber according to the invention showing the outside of the chamber and a slit valve opening through which a substrate for processing can pass;

Figure 2 is a partially exploded perspective view of the chamber top of Figure 1, the inner slit valve door and its actuator are shown separated from the top flange of the processing chamber;

Figures 3A and 3B are exploded perspective views of the pieces of the inner slit passage door actuator and slit valve door according to the invention;

Figure 4 is a top view of the slit passage door and actuator mechanism according to the invention; Figure 5 is a cross-sectional side view of a configuration of a vacuum processing chamber according to the invention showing the use of an external slit valve door and internal slit passage door in relationship to the substrate processing location of the processing chamber;

Figure 6 is a cross-sectional view of the actuator mechanism for the internal slit passage door according to the invention with the door in an up position;

Figure 7 is a cross-sectional view of the actuator mechanism as shown in Figure 6 with the slit passage door according to the invention in a lower closed position;

Figures 8, 9 and 10 are progressive assembly steps for moving the slit passage door into position and securing it to its actuator showing the installation steps and the clearances between the inner slit valve door according to the invention and a liner configured to receive the inner slit valve for the door;

Figure 11 is a cross-sectional view of a slit passage door according to the invention showing the location and configuration of lift rods which connect the actuator above;

Figures 12 and 13 show respectively the connections between the slit passage door and the lift rods, Figure 12 showing a fixed connection while Figure 13 shows a floating connection; and

Figure 14 shows a top view of the slit valve door showing the slotted opening for the floating lift rod of the door.

DETAILED DESCRIPTION

Figure 1 shows a perspective view of a typical semiconductor wafer processing chamber 20. A frame 22 supports a chamber body 24. The chamber body 24 at its front side has a slit valve passage 28 with an outer slit valve door (that cannot be seen in Fig. 1) to seal the chamber and a chamber top assembly 26. Adjacent to the chamber top assembly 26 is an inner slit passage door actuator assembly 30 shown with its cover removed. Note that the inner slit passage door actuator assembly 30 is on the same side of the chamber body 24 as the slit valve passage 28 and the outer slit valve door (which cannot be seen) through which wafers are passed into and out of the chamber 20.

Figure 2 is a partially exploded perspective view of the chamber liner and top assembly 40 including the inner slit passage door actuator assembly 30. A chamber top plate (or flange) 42 at its center supports a top plate electrode cover 44 and on the side adjacent the slit valve passage supports the inner slit passage door actuator assembly 30 which is located by dowel holes 46, 48. A pair of door lift rods, the left rod being the fixed lift rod 200 and the right rod being the floating lift rod 210 pass through their respective holes in the chamber top plate 42 to fit into holes in the top of inner slit passage door 60. As can be seen in Figure 2 the inner slit passage door 60 is curved to match the radius of the chamber liner assembly 50. The inner slit passage door 60 is attached to the lift rods 200, 210 by a rod retaining screw 72 and a shoulder screw 82, respectively. The inner slit passage door 60 fits in a slit door recess 54 in the chamber liner assembly 50 so that when the inner slit passage door 60 is in its down position, it covers and overlaps the slit opening 52 in the liner assembly 50.

Figures 3A and 3B show an exploded perspective view of the parts of the inner slit passage door 60 and vertical actuator assembly 30. A top view of the assembled actuator assembly 30 is shown in Figure 4, while a detailed cross-sectional view of the actuator assembly is shown in Figure 6. In the description that follows, all of these Figures should be referenced to thoroughly understand how the door support rods 200, 210 support and precisely position the inner slit passage door 60 as it moves up and down.

An actuator base 100 is supported on the chamber top plate 42 (for example, as shown in Figure 2). The base 100 includes a large dowel pin 186 and a small dowel pin 188 (Fig. 6) which fit into large and small dowel pin holes 46, 48, respectively, in the chamber top plate 42. The dowel pins fit tightly in these holes and their two different sizes prevent an incorrect installation. The lower surface of the actuator base 100 includes a set of two O-ring grooves each having an O-ring seal (e.g., 132, 134) surrounding the lift rods 200, 210 passing through openings in the bottom of the actuator base 100. A set of two bellows mounting tubes 102, 104 which are integral with the base 100 extend

vertically from the bottom portion of the base to provide an enclosure for a set of rod lifting bellows assemblies 120, 140. Each rod lifting bellows assembly (e.g., 120, 140) includes an intricately assembled set of pieces which guide each of the lift rods as they move up and down and restrict their sideways motion while maintaining a vacuum seal across the bellows without any rubbing parts. Each rod lifting bellows assembly (e.g., 120, 140) includes a bellows central rod 128 which extends from a top of the assembly all the way through to its bottom. At the bottom of the assembly, a lower rod receiving portion 121 includes a threaded hole for receiving an upper end (e.g., 202) of one of the door lift rods (e.g., 200, 210). The lower portion 121 of the central rod 128 extends down below a lower bellows flange 122 that extends laterally outward from the central rod 128. At the perimeter of the lower bellows flange 122, a cylindrical set of corrugations form a cylindrical bellows attached to the perimeter of the flange 121. The upper end of the cylindrical bellows 123 is welded to an upper bellows flange 124. The perimeter of the upper bellows flange 124 extends out over the end of the top of the bellows mounting tube 102 and includes a downwardly facing inner recess to fit over a raised inner ledge/seal flange 114 (Fig. 3A) of the bellows mounting tube 102, against which a sealing O-ring 106 is positioned. The bellows flange 124 at its center includes an upwardly extending guide bearing support tube 126. A tightly fitting lower rod guide bearing 125 is supported at a lower end of the guide bearing support tube 126, while an upper bellows rod guide bearing 127 is supported at an upper portion of the tube. A travel stop tube assembly 150 includes a lower flange 152 and a tube portion 154. The lower flange 152 sits on and seats against the upper bellows flange 124 and the upper surface of the bellows mounting tube 102. The travel stop tube assembly 150 surrounds the guide bearing support tube 126. The tube portion 154 of the travel stop assembly 150 extends to a tube end 158 which has an O-ring groove 156. An O-ring 168 is placed in the O-ring groove 156 and acts as a bumper to dampen the shock of stopping when the actuator assembly moves down and contacts the end 158 of the travel stop tube assembly 150. The travel stop tube assembly 150 acts as a hard stop to prevent further downward motion of the inner slit passage door 60.

The upper end of the bellows central rod (e.g., 128) is connected to a floating joint 174 which restricts vertical motion (Z-axis) but allows X-Y axis motion and also angular (spherical-type tilting) between the two halves of the joint. This floating joint allows for minor misalignments without creating any binding forces that might prevent an easily operable vertical stroke.

At the bottom end of the bellows central rod 128 a top end of the fixed lift rod 200 includes a threaded portion which is threaded into the hole in the lower portion of the bellows central rod 121 and also includes a flange which acts as a stop to tightly control the overall vertical dimension of the fixed

lift rod 200 with respect to the bellows central rod 128. The flange contributes to achieving the tight tolerance in vertical positioning (spacing) that is very important in this configuration so that a specified gap between parts is maintained, but touching of such parts does not occur. In the configuration as shown, the lower portions of the two central rods shown, as will be discussed in detail later, are fixed to the inner slit passage door 60 by the fixed screw 72 and the shoulder screw 82.

Compared to the left side rod lifting bellows assembly 120 described above, the right side rod lifting bellows assembly 140 contains identical components and is sealed to a right side seal flange 116 by an O-ring 108 (Fig. 3A). The top end of the right side rod lifting bellows assembly 140 is also enclosed by a travel stop tube assembly 160 which contains an O-ring bumper 170 at its top surface and the central bellows rod of the right side (floating side) can connect to a right-side floating joint 176.

The two floating joints 174, 176 are connected at their top ends to a rod lift cross member 180 which is rigidly fixed to the pneumatic actuator rod 112 of a pneumatic actuator cylinder contained in a pneumatic actuator base 110 by a pneumatic actuator connection bolt 182. The limit of the upward vertical motion is set by the limit on the pneumatic actuator 110 and the motion limits of the pneumatic rod 112. High pressure air (for example, 60 to 80 psi (0.414 to 0.551 MPa)) is commonly used to move the actuator up or down as required. With such high pressure, the force will be fast acting and the rigidity of the pneumatic actuator rod 112 along with its tight clamping to the rod lift cross member 180 along with the use of floating joints 174 and 176 prevents there from being any binding as a result of the door lift rods or the bellows central rods being out of alignment with the pneumatic actuator 112.

Figure 6 pictures the fully up position of the inner slit passage door 60 positioned above the top edge of the slit opening 52 in the liner assembly 50.

Figure 7 shows the same elements of the actuator assembly as in Figure 6 but the inner slit passage door 60 is shown in its lowered position and the positions of all actuator elements correspond to their positions when the rod lift cross member 180 contacts the tops of each of the travel tube assemblies 150, 160 to prevent the door 60 from descending further. In this configuration it can be seen that the inner slit passage door 60 overlaps the edges of the slit opening in liner 52 by an equal amount all around of approximately one half inch.

The vacuum limits of the processing chamber extend into the actuator assembly. The O-rings 132, 134 which seal the bottom of the actuator base 100 against the top of the chambered top plate 42 provide one seal. A second seal is provided by the O-rings 106, 108 configured between the upper bellows flanges (e.g., 124) and the top end flange/lip 114 of the bellows mounting tube 102 (Fig. 3A).

The cylindrical bellows corrugation (e.g., 123) which is welded between the lower bellows flange 122 and the upper bellows flange 124 completes the sealing/separation between the atmosphere and vacuum while still allowing the actual vertical movement without their being any particles generated as a result of rubbing two pieces within the vacuum chamber. The guiding of the central rod (e.g., 128) by the linear guide bearings (e.g., 125, 127) in the bellows assembly is located in atmosphere and particles thus generated have no effect on processing within the vacuum chamber.

An element of the proper location of the inner slit passage door 60 and its movement are the tight dimensional tolerances specified for the base 100. The use of an integral large base which is dimensioned and toleranced very tightly (several thousands of an inch in most instances) assures that appropriate dimensional relationships between the inner slit passage door 60 and the adjacent liner assembly 50 are maintained.

Figure 4, a top view, shows the curved configuration of the inner slit passage door 60 with respect to the two rod lifting axes of the bellows assemblies 120, 140 as positioned on the base 100 of the actuator assembly 30.

Figure 5 shows an elevational cross sectional view of a processing chamber with a substrate processing location 220 being located opposite a substrate transfer passage 222 such that a slit valve door 224 at the outside of the passage and the inner slit passage door 60 obstruct the passage of a substrate from the outside of the chamber to the substrate processing location 220. The slit passage actuator assembly 30 is located above the inner slit passage door 60 (some internal elements of the actuator assembly are not shown in this view).

Figures 8, 9, and 10 show the progressive installation sequence of the door 60 using cross sectional views along the vertical hole passages through the door which mate with the door lift rods 200, 210. In Figure 8, the lift rod 210 is shown in a retracted (up) position with respect to the chamber top plate 42.

The inner slit passage door 60 has a lower counterbore bolt hole 61, a narrow pass through hole 63 and a top rod receiving hole 65. During assembly, the inner slit passage door 60 is moved into position under the door lift rods in the liner assembly 50. The construction of the inner slit passage door 60 is such that the thickness of the door, (more particularly the position of its front face) changes from top to bottom such that there is a lower beveled face 62 at the bottom portion of the slit passage door 60, there is uniform thickness face area 64 (which here is shown straight (i.e., vertical), but in an alternate configuration may be may be slightly angled or beveled) and an upper beveled face 66 where the thickness of the door increases towards the top. The beveled faces match lower 84 and upper 86

beveled faces on the liner inner wall portions 94, 96 such that when in position as shown in Figure 10, the gaps (e.g., 88, 90) between the front faces (62, 66) of the inner slit passage door 60 and the facing liner upper and lower surfaces (84, 86) are approximately several tens of thousandths of an inch (several times 0.254mm).

The gap dimensions (e.g., 88, 90) are maintained to prevent any plasma (and processing byproducts such as polymers) from moving into the substrate transfer passage 222 as it does in the prior art. Further this gap is large enough so that the risk of the door touching (rubbing against) the liner during operation is minimized so that particles are not created, but the gap is tight enough so that plasma is choked and chemical byproducts (byproducts of the processing which tend to coat the surface of the processing chamber facing it) cannot pass through. Further build up of films which do deposit on the surface of the inner passage door 60 have a minimal effect in that the bevels on the face of the liner and the matching top and bottom and partial beveled surfaces bevel in the slit valve door mean that the closest approach between the liner and the door is when it is in a fully closed position. As soon as there is any motion to the open position, the gap, for example as shown in Figure 9 and 10, gap dimension 90 in Figure 10 increases tremendously to become gap dimension 92 in Figure 9.

Figure 3B shows in a perspective view the beveled orientations of the upper and lower chamber liner portions 94, 96 with their respect to faces 84, 86. The end 56 of the slit opening 52 is positioned short of the edge of the recess 54 in the liner assembly 50 so that once the inner slit passage door 60 is put into position the end of the door overlaps the end 56 of the slit 52 by a distance approximately equal to the overlap of the top and bottom edges as discussed above.

The progression of the assembly is shown in Figures 8, 9, 10. The retracted door lift rods receive the inner slit passage door and retaining screws are inserted and tightened so that the door can then be actuated. A frontal view of the door with the lift rods 200, 210 as shown in Figure 11 as might be expected, the door being made of aluminum will tend to expand and contract with variations in temperature, as will doors made of any material that has a coefficient of thermal expansion that tends to create binding on lift member depending on the dimensional relationships established and the range of temperatures to be accommodated.

The requirement of positional accuracy and the freedom for thermal expansion is accommodated by making one door support rod, the left rod 200 here, a fixed rod such that the end of the rod 200, for example, as shown in Figure 12 is tightly clamped to the fixed hole configuration in the slit valve door. The machine screw 72 engaging the end of the rod tightly clamps the end of the rod 200 to the shoulders of the narrow pass through hole 63 in the inner slit passage door 60. This

tight clamping provides a good electrical path to ground from the door, so that the possibility of arcing is reduced or eliminated, and further sets a horizontal and vertical position of one end of the door. This clamping acts as an anchor (or pivot) around which the other floating end of the door and its support can move.

Figure 13 shows the right-hand rod, floating rod 210. Its rod receiving hole 68 is elongated in a sideways direction (e.g., Fig. 14) to allow for some expansion and contraction while the lower end of the rod is vertically fixed by a shoulder bolt 82 which clamps tightly against the bottom end of the floating rod 210. The narrowness of the slot 68 prevents sideways (radial) motion. Note that there is a gap 74 between the end of the rod and the inwardly protruding flanges (shoulders) of the rod through hole 63. The floating rod can thereby tilt, but is vertically fixed by the end flange (head) of the shoulder bolt 82 to allow free contraction and expansion of the slit passage door 60 as temperature variations take place about the fixed central axis of the fixed lift rod 200. Since the temperature variation is only approximately 100 to 150 degrees from ambient and the distance between the two lift rod holes is approximately six inches, the expansion will be quite manageable with this configuration.

A configuration according to the invention as has been described above typically includes an outer (chamber sealing) slit valve assembly. The present invention provides an inner slit passage door to block the deposition of polymers and other byproducts of the process in the chamber from depositing on the wall of the processing chamber. In this configuration the inside of the outer slit valve door does not have to be cleaned during a normal cleaning of the processing chamber. Therefore, the seal between a transfer chamber of a cluster tool is not affected if one of the chambers needs to be cleaned, whereas in the past, chamber cleaning always meant that the cluster tool and its transfer chamber was disrupted. Another benefit of a configuration using an inner slit passage door as described herein is to improve the uniformity of the distance between the edge of the substrate being processed at the substrate processing location in the chamber and the surrounding liner which defines the limits of the plasma envelope over the substrate. In the conventional configuration there was a large hole in the chamber liner which allowed plasma to expand into it. The expansion of plasma created a distortion on the plasma flux over the substrate being processed and variations in substrate processing from the side closest to the substrate transfer passage to the opposite side were noted. In a configuration according to the invention, the discontinuity in the plasma flux due to the slit transfer passage has been eliminated, by the substitution of a door at the same electrical potential as the liner, to create a nearly uniform distance between the edge of the substrate being processed and the liner lining the wall of the processing chamber adjacent to the substrate. The configuration accomplishes this

without substantially increasing the risk that particles will be generated in the chamber either by the movement of a dry door, or by movement of a door whose exposed surfaces have been coated with process byproducts. The bellows assembly seal provides dry sealing, without introduction of particles, while the cleverly curved and/or beveled surfaces of the door and the liners surfaces that it faces reduce the risk of polymer flake off, and peel off during operation. The door can be easily removed and cleaned as a unit with the liner assembly thereby simplifying the maintenance steps need to achieve a clean chamber, to return the chamber to production as soon as possible.

While the invention has been described in regards to specific embodiments, those skilled in the art recognize that changes can be made in form and detail without departing from the spirit and scope of the invention.